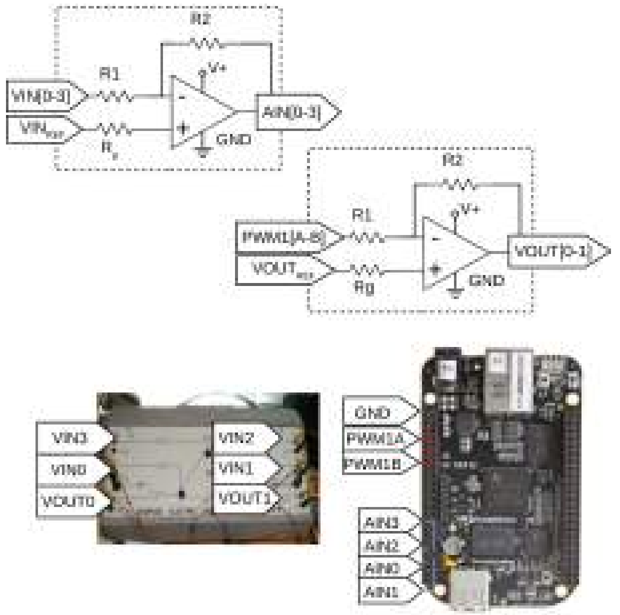

FIGURE 5. **The plant and the board work at different voltage levels, so an op-amp based circuit was added to each I/O to obtain the adequate ranges.**

an amplifier with gains chosen according to the ranges, see Figure 5).

III. ACTIVITIES WITH THE WEB-LAB

Some of the activities described in this section can be performed only in simulation with the virtual laboratory while others can also be performed in a real way with the remote laboratory. Usually, our students work first with the virtual version to acquire experience and to practice with the theoretical behavior of the system. Then, they work with the physical system in order to contrast the results obtained from the real experimentation with those obtained from the simulation. The following paragraphs explain the main activities to be performed with this web-lab.

A. SYSTEM IDENTIFICATION

This activity is only performed in simulation mode. One of the VL's main purposes is to identify the system or to gather useful information about the order of the system and the values of zeros and poles. This activity may be performed acquiring data from all the steps in the simulation:

- The open loop analysis returns information of the dominant pole, as happens with first order systems, and the over-damped step response delimits the value of damping factor, as happens with second order systems.
- A most accurate damping factor and the natural frequency can be obtained by perturbing the system. This allows determining the value of the complex pole pair.
- The frequency response analysis provides detailed information of the transfer function. This can be used for checking results of previous activities, for explaining the differences with a second order system, or for fitting with a better model (identifying the other two real poles).

Students who have obtained an accurate model of the coupled drives system in the virtual laboratory will be able to program better controllers or tune better PID parameters to get the desired response. In addition, they get better prepared for the remote laboratory where the system identification is not easy. If the students want to obtain a model for the real system they must take into account the results in virtual application, and then, fit the parameters of their models using the outputs of the remote lab.

B. PID TUNING

When the automatic control mode is selected in the upper menu (as described in the previous Section), a closed loop is established for controlling the velocity or tension of the belt by means of a PID controller. In coupled mode, students can select the control variable (either velocity or tension) in this MIMO system, and may change the proportional, integral and derivative parameters of the PID controller (k_P, T_I, T_D) in order to obtain a response that satisfies the specifications asked in the practice guide. In decoupled mode, students work with two SISO systems and, therefore, with two PID controllers. Then, an analysis of the output signals (stored in .m files), allows to obtain an approximated model of the system. This activity can be performed in both the virtual and the remote laboratory.

C. FREQUENCY RESPONSE ANALYSIS

The web-lab allows modifying the values of the frequency (ω) and amplitude (A) of a sinusoidal input signal:

$$u_{in} = Asin(\omega t)$$

By introducing such an input and registering the magnitude and phase estimations from the *AC Signals* graph in the evolution window, students can obtain the magnitude-frequency and phase-frequency graphs (i.e. a Bode plot).

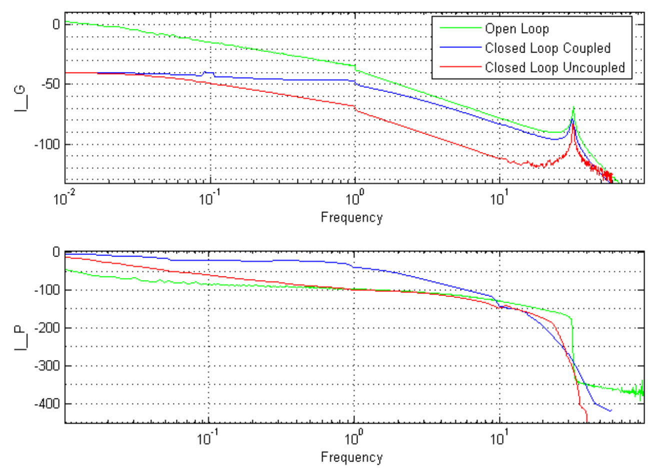

FIGURE 6. **Magnitude-frequency graph of the open loop and in closed loop (for coupled and uncoupled control).**